Status Report: Census of Lingcod Nesting Activity in the Edmonds Underwater Park

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Abstract
Progress of the ongoing effort to document lingcod nest sites in the Edmonds Underwater Park is presented. The census is done by a team of volunteer divers to measure reproduction of the fish as a general indicator of the overall health of the site. The Edmonds Underwater Park was one of the first underwater parks and is arguably one of the most popular sites for scuba diving on the North Pacific coast.

Regular visitors are aware of remarkable increases in the quantity and variety of marine life in the park over the past decades. Habitat is entirely artificial is somewhat isolated from natural lingcod habitat. The park fits most definitions of a Marine Protected Area (MPA), and predates the coining of the name. It has been a marine sanctuary since 1970. Survey methods and procedures presented at the 2001 Research Conference are briefly reviewed and survey results updated. The park typically provides more than 60 nest sites per season. Seven years of survey results will be discussed. Among the continuing observations is strong evidence of repeat usage of specific sites and repeat use of a site by individual guard fish. The effort is a statement about stewardship in action and the value of volunteer teams.

Introduction
Status is provided of the ongoing effort to document spawning activity of lingcod, *Ophiodon elongatus*, in the Edmonds Underwater Park (EU/WP). A volunteer team has been documenting the nesting activity of lingcod in the park for the past seven years. Initial effort was focused on validating that the task was within the capability of a non-professional team of volunteer divers. Emphasis was placed on development of methods and protocols. The conclusion that volunteers are able to conduct the census was presented in the proceedings of the last research conference, (Johnson 2001). Subsequent findings, both refinement and addition to initial data as well as new information are the primary material presented herein. For purposes of clarity and context, information from the prior material is included in abbreviated form.

The Edmonds Underwater Park (EU/WP) is located in the northern part of the Seattle metropolitan area on the eastern shore of Puget Sound (Lat. 47 49.00, Long.122 23.00) in Washington state. The park has been a marine sanctuary since 1970 and is one of the oldest refuges on the Pacific coast. It is also a popular recreational scuba diving site.

Lingcod were selected for the census because they are an important and visible denizens of the park. The conspicuous white egg masses and aggressive behavior of the nest-guarding male lingcod make the task of finding the nest sites straightforward, and the simple attributes measured are achievable by unsophisticated means.

Purpose
The census is intended to gather information about lingcod nesting activity to compare to and update the established baseline. The data provide a record to evaluate the effect of physical and biological changes as well as successes and failures of management practices. An attempt will be made to identify the factors that are attractive to fish and marine life as a guide to future enhancements.

Prior investigations of lingcod spawning activity (Jewell 1968), (Low and Beamish 1978), (LaRiviere, *et al.* 1981) and (Giorgi 1981) are succinctly summarized by Cass *et al*. (Cass *et al*. 1990). O'Connell (O'Connell 1993) investigated deep water spawning in Alaska. Unique aspects of the subject study are the sustained time period involved and the artificial habitat in which the lingcod spawn. The method used in the study was patterned after surveys by the Vancouver Aquarium in Howe Sound, B.C. Canada (Martell 1997) and have been adapted for use as a census in this study. The methodology and protocols used are described as well as the first five years of census activity (Johnson 2001), and will be repeated in summary form herein for continuity.

Background

The nearshore of Puget Sound in the vicinity of the underwater park is primarily sandy bottom. A region of cobble and glacial erratic rock north of the park provides anchorage for a kelp bed in the summer months. The shoreline in the vicinity is hardened by railroad road bed. At the turn of the last century saw mills were located at the site of the park and the substrate is still infused with woody debris. A ferry terminal is located adjacent to the park on the south side. In the mid-thirties a derelict metal dry dock was sunk just north of the ferry terminal. This was supplemented in 1971 by the wooden hull of the motor vessel, Alitak, on the shoreward side. Other man made structures in the area south of the park includes the oil pier at Edwards Pt and the breakwater at the Edmonds Marina. In the late seventies, a fishing pier that included artificial tire reefs was built.

Since 1979 structures have been added within the park to provide interest to divers and to enhance the marine habitat. The added features are arranged as isolated structures on the sand bottom in an "oasis" pattern. Materials used include stone and concrete rubble, concrete beams and arches, concrete and plastic pipe, large hollow concrete blocks, and a variety of boat hulls. The Edmonds Underwater Park and surrounding area are geographically isolated from the rocky reef habitat usually associated with lingcod.

Materials and Methods

Volunteers divers conducted field work observations on weekends, primarily Saturdays. Participating divers were divided into teams and each team surveyed a portion of the park. A flexible rotation schedule insured that all portions of the park were visited on a regular basis, several times within the maturation period of a viable egg mass. The indefinite nature of volunteer diver participation made a rigid survey schedule impractical.

Surveys were done by divers using standard scuba equipment. All dives originated from shore. The goal of the divers was to locate all of the egg masses within the park boundaries. Egg masses protected by guard fish were marked as a nest site. A nest site is defined to be the territory defended by the male guard fish. Egg masses that were loose on the bottom or unguarded were not marked.

A numbered plastic tag was affixed near each new nest site when the eggs were first detected. The tags were white with black lettering and were attached with nylon tie wraps. These tags were intended to last for one spawning season and were replaced each season.

All of the data was from *in situ* visual observations. Simple tools were used to collect data about the nest site, the egg mass, and the guard fish.

A standard format slate was used to record the data. Survey parameters were standardized to encourage consistency of observations. The slate has a legend of the standard terms/attributes. A sheet of instructions was provided to assist the volunteer diver in recording consistent data.

A narrative description of the nest site was made. The description was sufficiently detailed to locate the nest site on a map.

The egg mass is a contiguous volume of eggs. There may be more than one egg mass at a nest site. The size of the egg mass and color of the eggs were recorded. The size of the egg mass was defined as the overall dimensions, the size of the rectangular box that would contain the mass.

Information descriptive of the nest site was recorded by specific standardized parameters and by general comments. The standard parameters included the height of the egg mass off of the substrate, the material upon which the eggs were deposited and the geometric characteristics of the cavity occupied by the egg mass. A cavity was judged to be sandwich or wedge shaped. Sandwich indicates approximately parallel sides; wedge indicates a wedge-like cavity. A kebob nest is spawned onto the retaining material encasing it as though skewered, like a kebob. The egg mass cavity was further categorized by orientation of the long dimension, either horizontal or vertical.

Guard fish parameters that were recorded include the overall length of the fish measured to the nearest 5 centimeters with a measuring stick. The color of the fish was noted. The behavior of the guard fish was also noted. Standards were provided for determining the coloration and behavior of the guard fish.

Information was also recorded on predation of the egg mass. The physical appearance of the guard fish was checked for markings such as scars and healed wounds that might serve as identification of individual fish. These and other unique characteristics were noted in the comment section.

The data was transferred to a spreadsheet database and the locations of nest sites were plotted on a map.

In addition to the slate, survey divers used a one meter long staff of plastic pipe graduated in ten centimeter increments used to aid in measurements. Photographs and video supplemented the data.

In addition to the seasonal plastic tag, previously used locations are in the process of being marked with a permanent identification number. These numbers are intended to stay with the site from season to season. Smaller brass tags with numbers stamped into the tag surface were used for these markers. A portion of the permanent tags are attached using tie wraps embedded in underwater epoxy after the spawning season.

A temperature recording probe was placed in the park for the 1999/2000 spawning season. It was programmed to provide temperature variation over the nesting season. Use of the probe was continued in subsequent seasons to collect data relating temperature and spawning activity.

Results and Observations

The survey effort is summarized by season in Table 1. An observation is defined as visiting a nest site and recording data. The total number of divers that participated each season is also shown.

Table 1. Survey effort by season

	Season					
Effort	**96/97**	**97/98**	**98/99**	**99/00**	**00/01**	**01/02**
Dives	31	68	76	61	75	86
Observations	109	182	215	335	316	463
Divers	11	24	14	14	18	18

The names of the divers in the dive teams that participate in the survey and the date are recorded on a sheet of the database. The regions within the park visited by the divers during the survey are recorded on a separate sheet of the database. An activity log of general information obtained on survey days during the census is maintained separately. The number of survey dives over the course of the 1999/2000 season is shown in Figure 1. Both dives per week and the cumulative dives over the season are plotted.

Data on the egg masses is summarized in Table 2. The number of nest sites for each season is shown; also the number of those that are repeat locations from the prior year, the average volume of the egg mass and the date the first nest of the season was found. About 30 % of the egg masses were in a location that had been used in a previous season. The observed size of the egg mass was the overall dimensions of the egg mass, the actual volume of eggs is less. A volumetric coefficient of .5 is appropriate to get an approximation of the actual volume of eggs. The first egg mass was usually found in early December.

Table 2. Summary of egg mass data by season

	Season						
Egg Mass_Data	96/97	97/98	98/99	99/00	00/01	01/02	02/03
# Egg Masses	----	----	68	98	111	150	----
# Nest Sites	30	48	59	88	99	111	----
# Repeat sites	----	13	19	26	31	34	----
Avg. Vol. (cm^3 xE-6)	----	----	472	678	734	981	----
First nest (date)	12/23	12/20	12/19	11/27	12/16	12/8	12/7

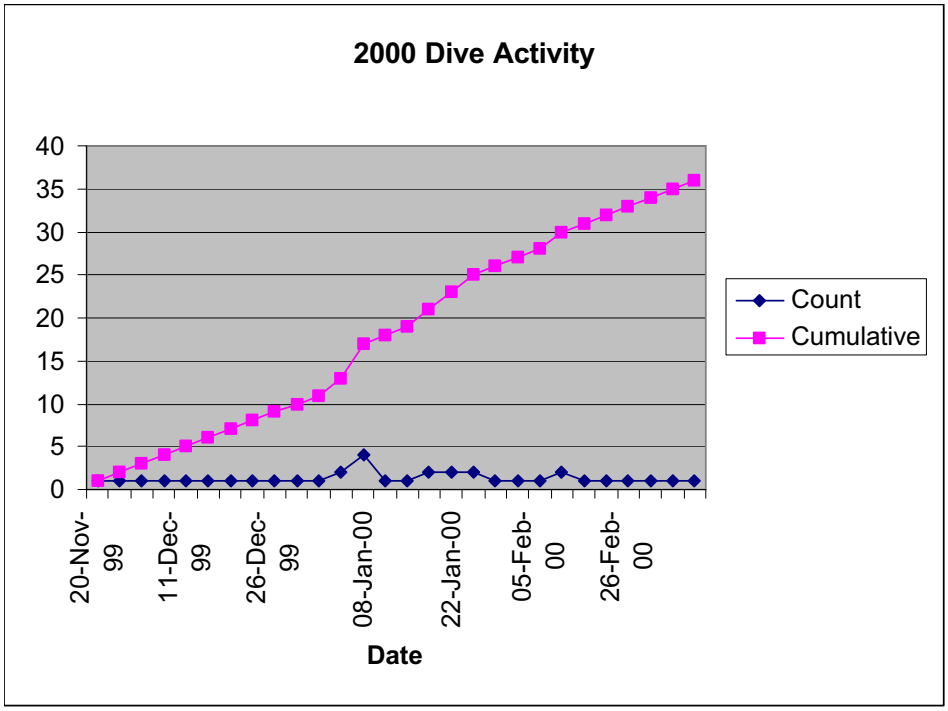

Figure 1.

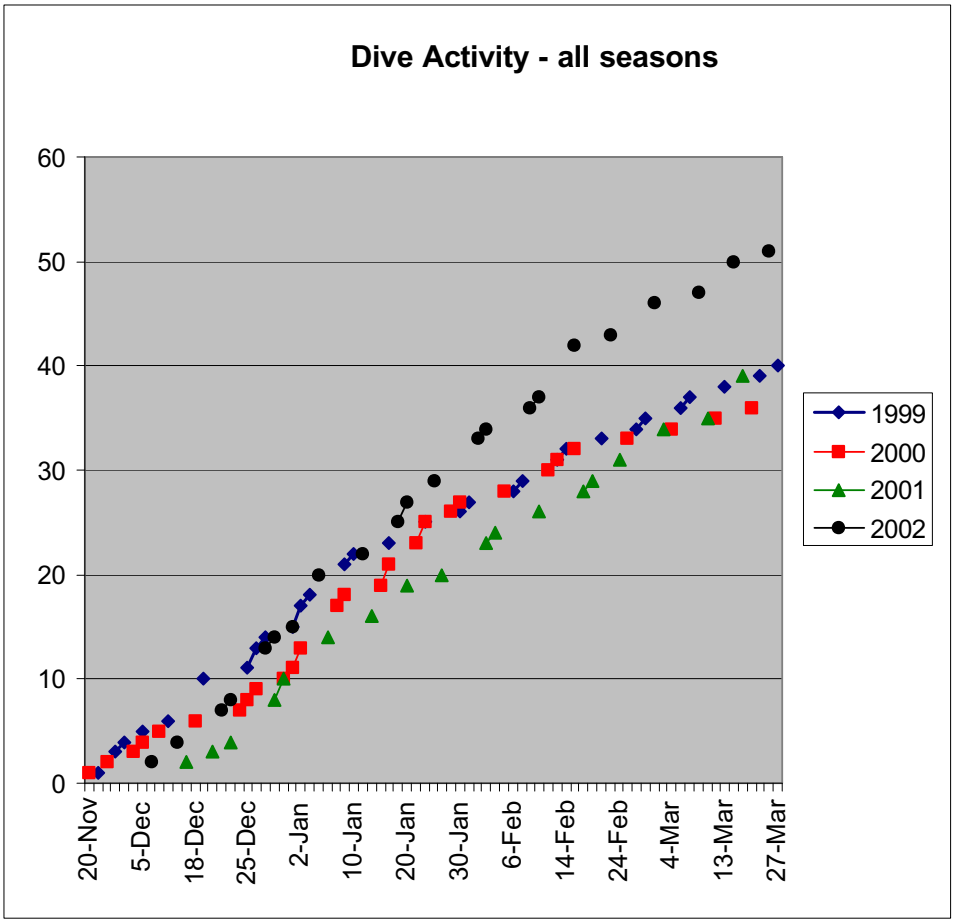

Figure 2. The cumulative dives per season for several seasons are superimposed

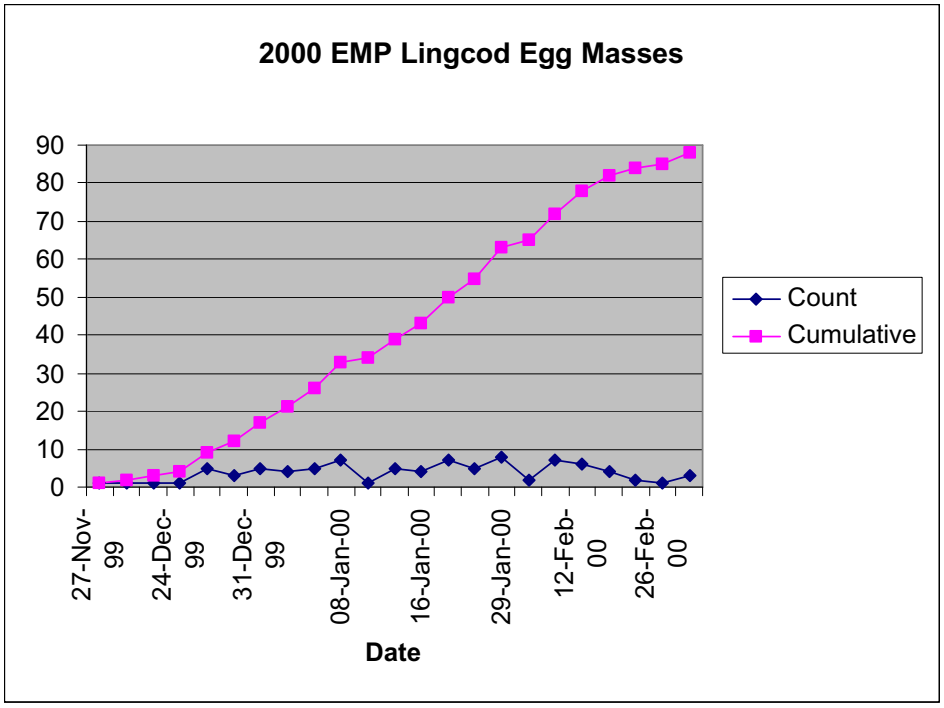

Figure 3. Figure 3 plots the number of new egg masses found each week over the length of the 1999/2000 season, starting at the first sighting. Both the number of new egg masses per survey day and cumulative number of egg masses over the season are plotted. Note that the number of egg masses, not the number of nest sites is plotted. The number of egg masses is greater that the number of nest sites owing to multiple egg masses at some nest sites.

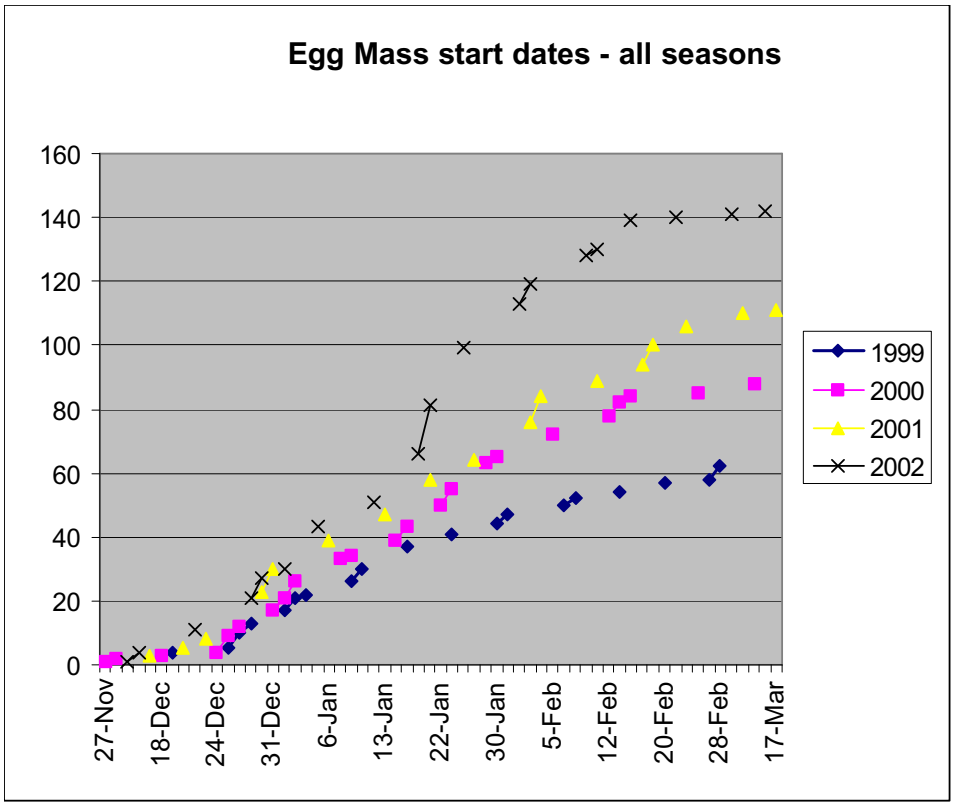

Figure 4. The plot of cumulative number of egg masses over the season for several seasons are superimposed.

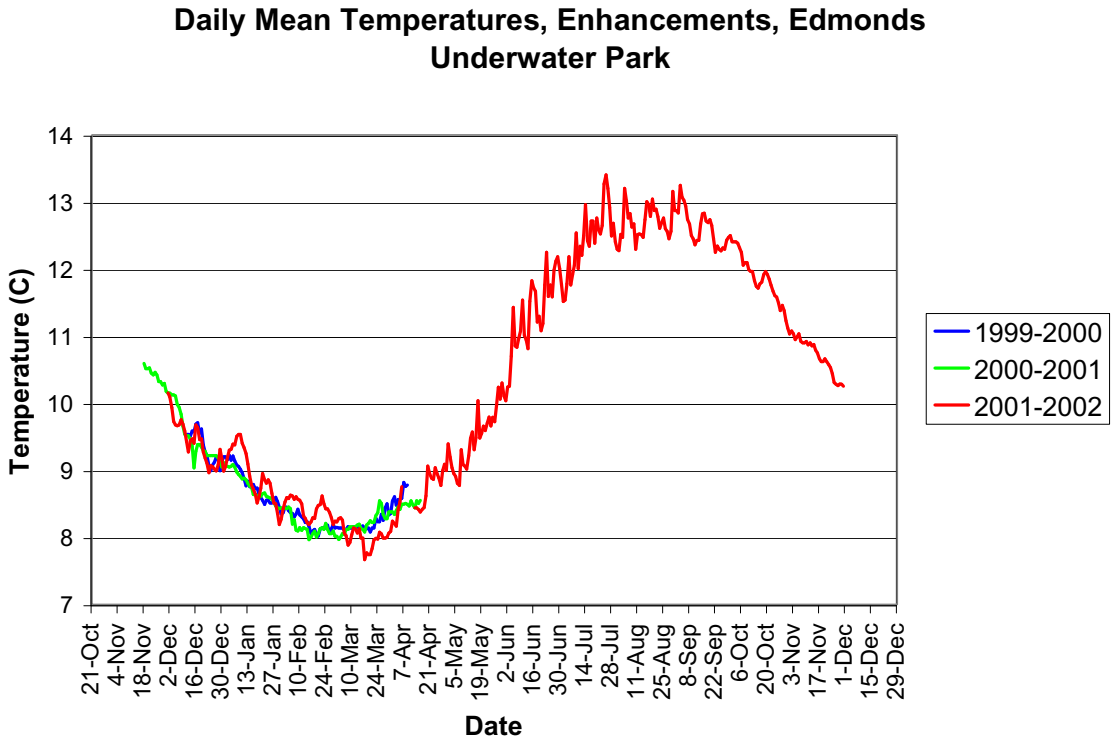

Figure 5. Distribution of guard fish by length (cm) in four seasons of observation

Color is a useful means of determining the approximate age of an egg mass. Freshly spawned eggs are a pearly pink color that changes to white and then dulls over the maturing period. The description of color change of the eggs is generally consistent with prior observations (Wilby 1937). The recorded color of the eggs can be used as an adjustment to the observation date to provide an approximate spawning date. This is being considered for future measures.

Figure 5 shows guard fish length over the seasons. Guard fish are grouped in 5 cm increments on the horizontal axis. The number of guard fish is shown on the vertical axis. A fairly consistent distribution of length is shown, indicating that younger fish are being recruited each season.

Information about guard fish is presented in summary form in table 3. The average length of the guard fish is just under 80 cm. The data suggests that while the average length is stable there is a trend of fewer large fish in recent seasons.

Table 3. Summary of Guard Fish Data by Season

	Season					
Guard fish	96/97	97/98	98/99	99/00	00/01	01/02
# measured	29	43	60	73	89	99
Avg. Length (cm)	77.1	78.4	78.3	77.3	76.5	77.2
%> 80 cm			27	18	16	10

Comparing the date that egg masses were first observed to the temperature plots indicates that spawning starts at approximately the same time as the ambient temperature falls below 9 degrees Celsius. The entire hatching time period occurs while the temperature is below 9 degrees Celsius.

The data of these tables and figures will be used as a baseline for future comparison.

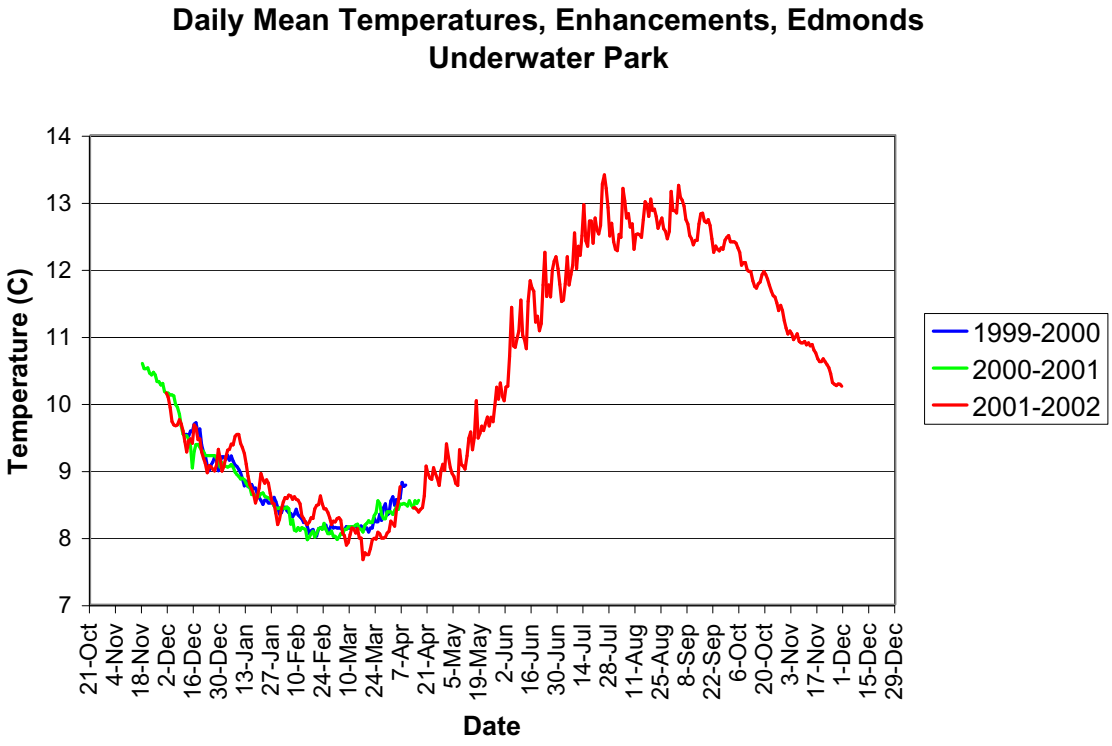

Figure 6. A plot of ambient temperature in the park during several spawning seasons and the temperature profile for one entire year are superimposed.

Discussion

Methods

Several changes were identified and implemented as improvements to the survey techniques. Others are recognized to need improvement. The method of marking nest sites has seen the most changes. Initially painted and numbered round flat beach rocks were used. Other methods that were tried included numbered pieces of white PVC pipe tied in place and numbered strips of fluorescent green survey tape. These were abandoned for the current method using numbered white plastic tags. The tags are attached near the nest site with nylon tie-wraps. The tags are visible enough to be readily seen by survey divers, aren't disturbed by the divers visiting the park, and don't upset the fish. The black numbers on the tags only survive a single season becoming unreadable from being overgrown by marine organisms. This is not a problem. Using new tags each season has proven to be useful in helping census divers determine which nest sites have been documented from those which have not.

Identification of nest sites with markers intended to survive for many seasons was recognized to be useful. The permanent markers will simplify description of the location during documentation and provide consistent identification of repeat sites. Some of the repeat sites have been marked with small numbered brass tags. Small polyethylene plastic tags with numbers imprinted have also been used. The plastic tags have proven to be difficult to read underwater. In the future only the brass tags will be used as permanent markers. The permanent tags have often proven to not be permanent, a portion having disappeared. In several cases where underwater epoxy was used the tags have come off due to the epoxy starting to catalyze before the attachment was made. The epoxy used is mixed before the dive, limiting the number of tags that can be done. Another difficulty has been finding the permanent tags, they are small and are often overgrown. In the future larger triangular shaped plastic placards will be located with the brass tags as an aid to locating them.

Current methodology does not include a standard way to capture quality of a measurement. Trying to measure a moving fish or a partially hidden egg mass can be difficult, especially when being harried by an irate guard fish. Consideration has been given to adding a quality attribute to the dimensional parameters. This would be useful in resolving data anomalies but would require a revision to the survey data sheet and the database.

A schematic diagram of the park was initially used to plot the nest sites. While this was adequate it was recognized that a more accurate map would be more useful, so one was produced. It has also been found useful to create smaller local diagrams to supplement the larger map. Several of these have been converted to digital format. In 2001, the NOAA ship Rainier performed a side scan sonar survey of the underwater park and local environs. The resulting map has been valuable in relative positioning of the features in the park and will aid in producing accurate smaller diagrams

Substrate

The data continues to indicate that there was not any particular substrate material that was refused by spawning fish. A variety of different materials, both natural and artificial, were available and were used. There also does not appear to have been a preference in the orientation or geometry of the cavity selected for the egg mass. There is strong evidence that nest sites will be selected on material recently placed in the park. There have been examples of egg masses spawned on substrate less than one week of having been placed. These new sites are more likely to be selected by younger (shorter, 60 to 75 cm in length) guard fish. This is consistent with many of the older (larger) fish having established sites that they revisit.

Egg Masses and Nest Sites

One of the questions that was hoped to be answered in the census is the status of the lingcod population in the park. Is it increasing, decreasing or stable; and what is the optimum population? The number of egg masses increased each season of the census, but this was in part a measure of the increased skill of the survey divers. Another factor was the increase in potential nest sites from year to year as new features are constructed. New features in the park typically host new nest sites immediately. Thus normalizing egg mass data by effort or total area is difficult. An attempt to establish an indicator has been initiated using specific sites to produce an index of egg mass volume produced for the area of the site. The Cathedral site has been selected because it was placed the year before the census began. The data for the site will typify the colonization of a new site. Figures 7.1 through 7.7 are diagrams of the nest sites at the cathedrals for each spawning season.

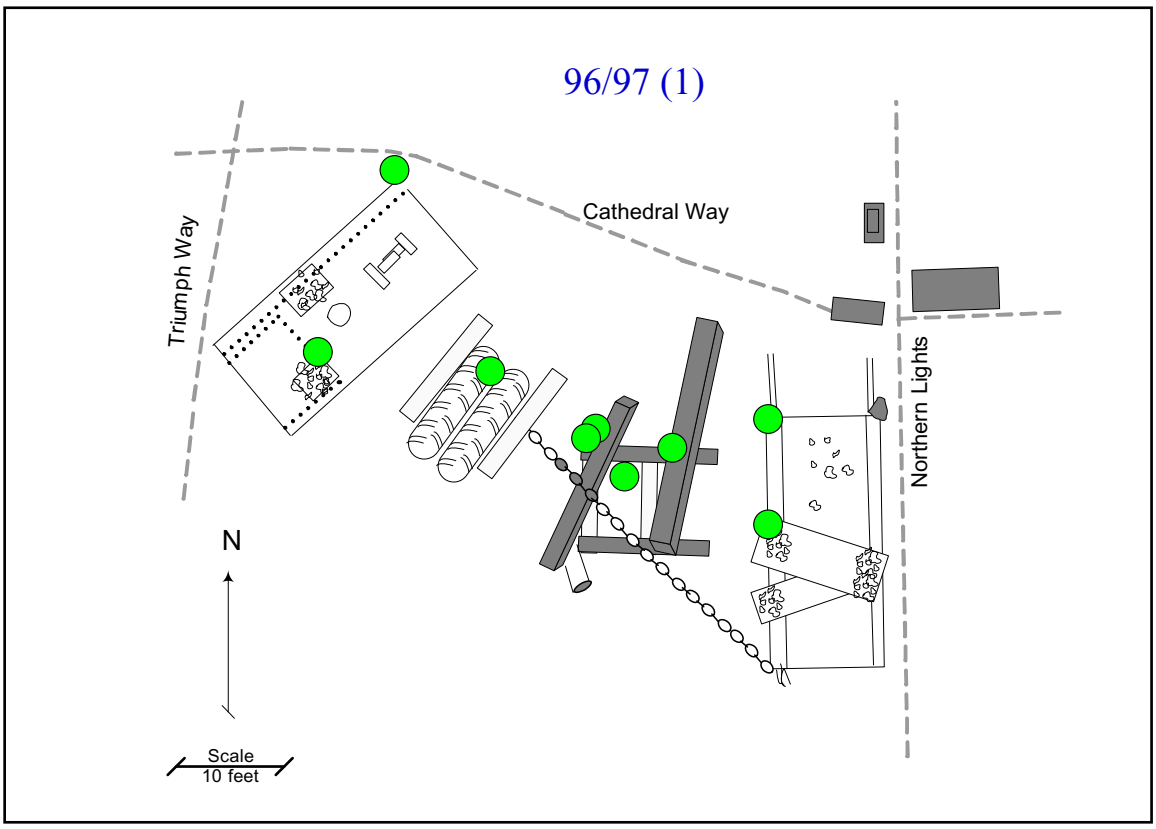

Figure 7.1

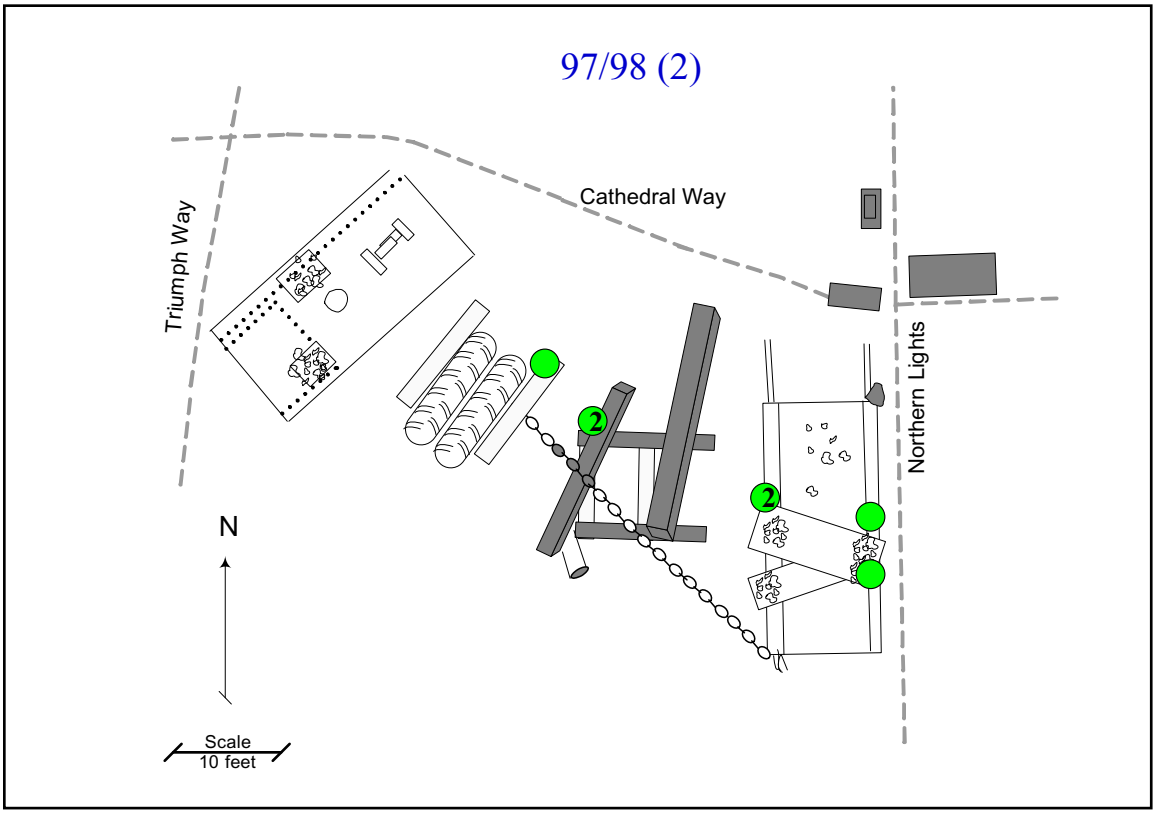

Figure 7.2

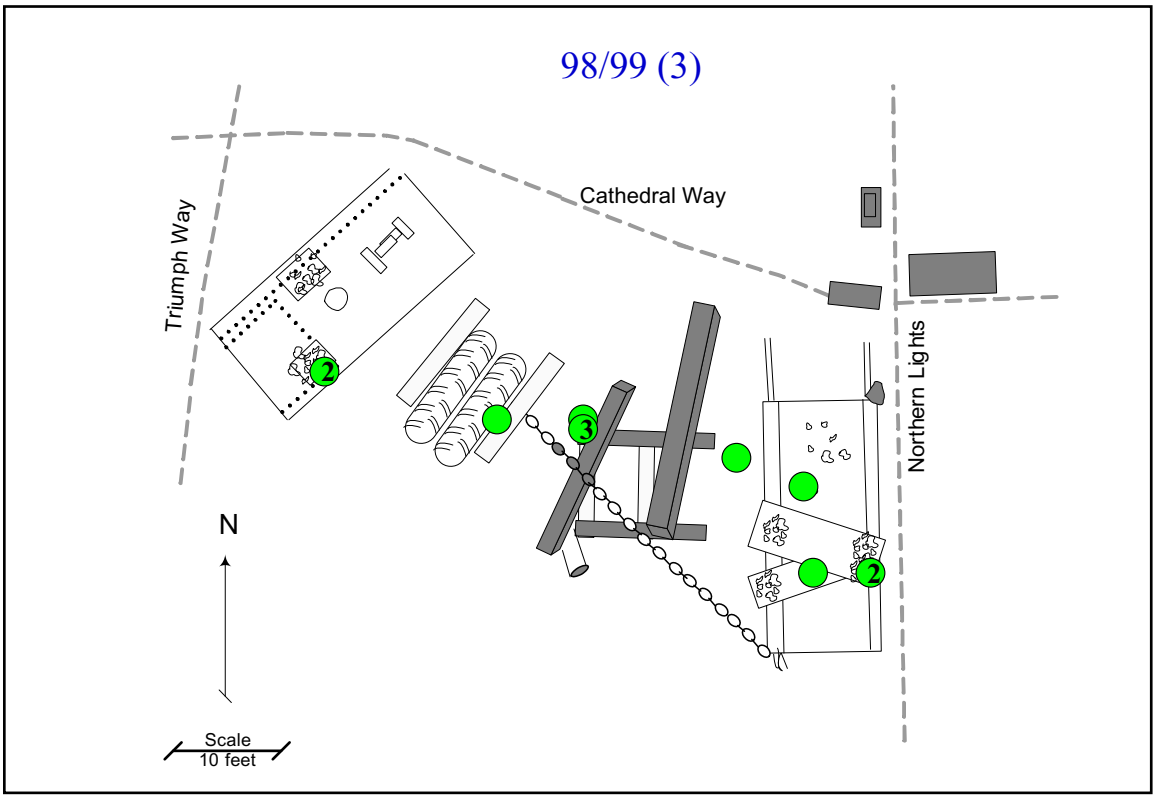

Figure 7.3

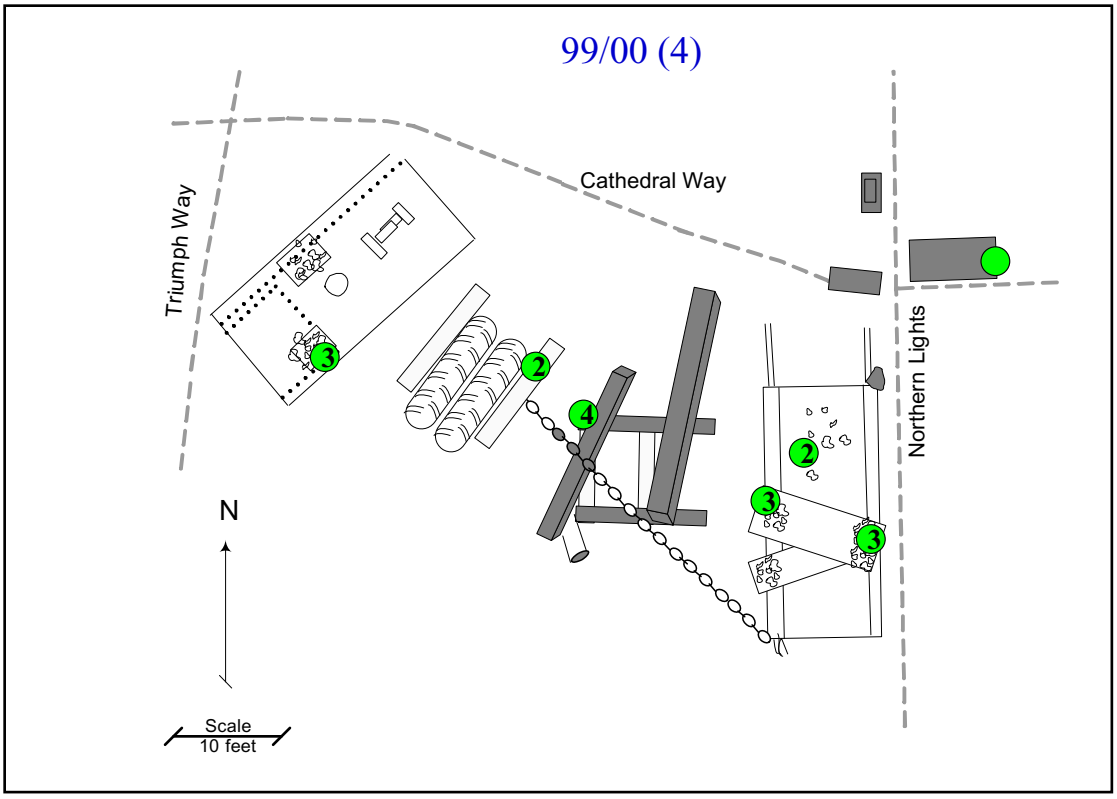

Figure 7.4

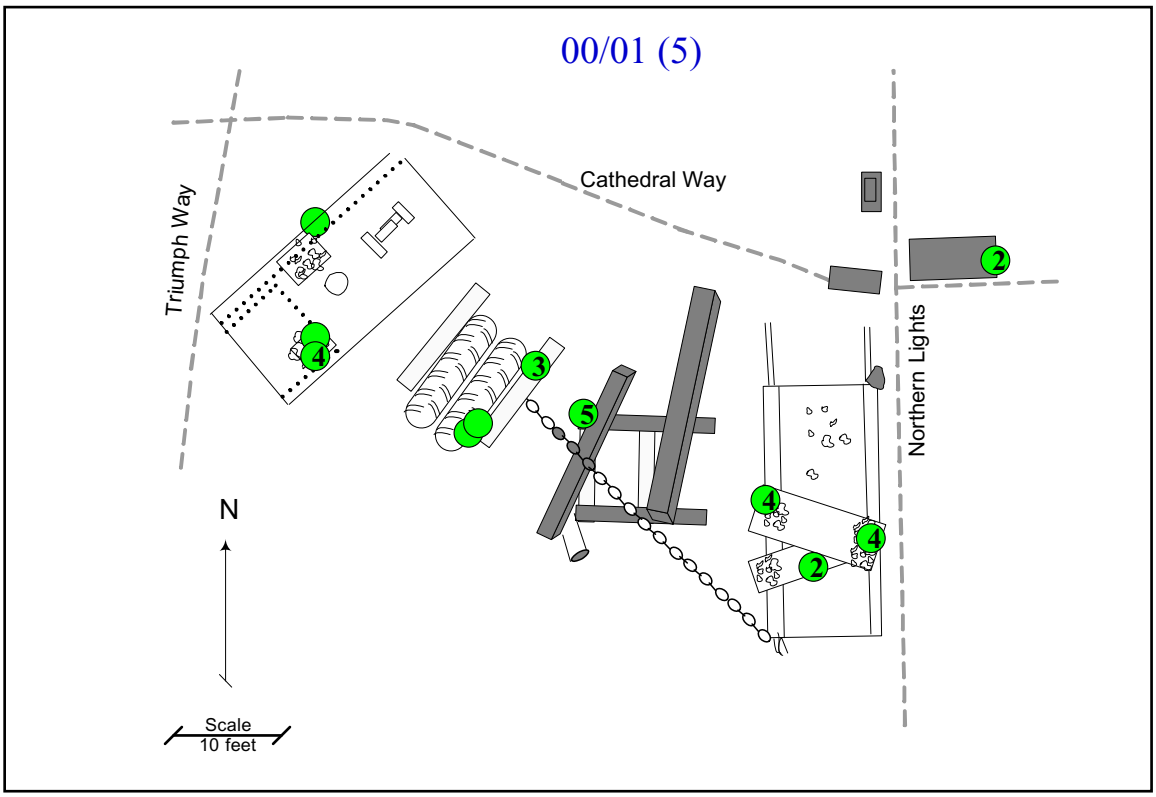

Figure 7.5

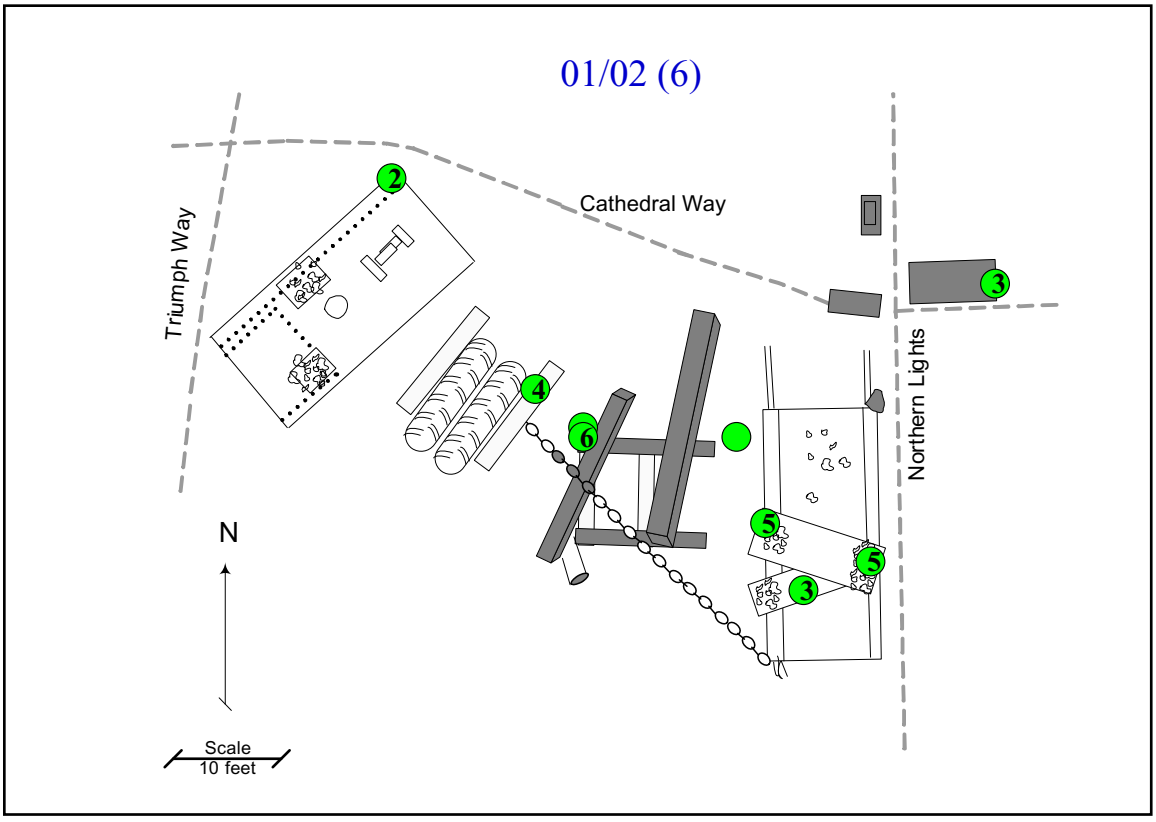

Figure 7.6

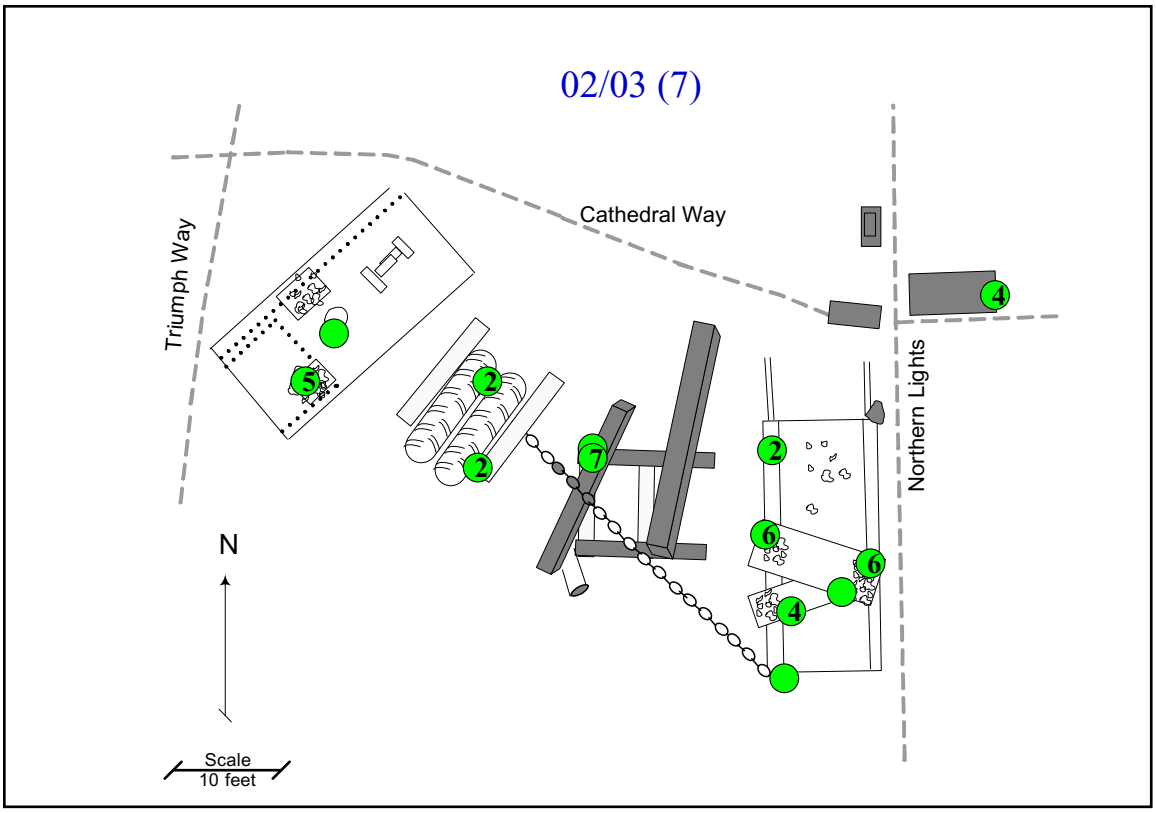

Figure 7.7

Table 4. Summary of the egg mass parameters for the cathedrals site by season.

Cathedrals over time

Season	Egg Masses	Sites	Repeats
96/97	9	8	-
97/98	5	5	2
98/99	8	7	3
99/00	7	7	6
00/01	11	9	7
01/02	9	8	7
02/03	13	12	9

Data will be compiled from survey results to produce similar diagrams and summary for the Alitak site. This site has been in place since 1971 so the spawning activity there is expected to be well established. Future results will compare these sites to their prior results and provide a basis for judging the status of the lingcod population in the park.

Predation

Predation on the egg masses as described is consistent with earlier observations of this census. Sun flower sea stars, *Pycnopodia helianthoides* have been observed engulfing egg masses. Guard fish have been observed biting and tearing at these sea stars, removing them from the site. On one occasion, a sun flower sea star had engulfed an egg mass. When the sea star was inverted so the remaining egg mass was visible, the guard fish who had been resting passively near the sea star, began to attack it, eventually freeing the remaining eggs.

Shrimp continue to be a major predator of lingcod eggs in the park. Most egg masses in the underwater park had shrimp on them and shrimp were observed carrying away small clusters of eggs and picking emerging larvae from an egg mass and consuming them.

Larval fish of a size and time frame consistent with lingcod hatching have been observed in shallow intertidal waters late in the spawning season. These larvae are typically observed swimming near the surface into the prevailing current. The larvae stayed above patches of eel grass (Zostera). When approached the larvae descended closer to the eel grass.

Guard Fish

It was not unusual for a male lingcod to guard more than a single egg mass. This is consistent with earlier observations. There have been instances of a fish defending multiple egg masses. One fish was guarding six egg masses in the underwater park. The greatest distance observed between egg masses defended by a single fish was 7.5 meters. The smallest distance between egg masses guarded by different fish was 1.2 meters.

Guard fish displayed varying degrees of aggressiveness toward the survey divers. While the larger males are typically more aggressive, very aggressive behavior was often observed in smaller fish. Some fish are more aggressive than others and will carry this trait forward from season to season. The aggressive behavior is also more prevalent in fish guarding multiple egg masses. Guard fish in the park have frequently exhibited damaged and tattered fins and wounds. Eye injuries are not uncommon.

Scarring from healed wounds enabled identification of six individual male lingcod from season to season. Three of them are missing and assumed to be dead. The following observations of the last sighting of one of the missing fish is excerpted from the survey records: “Nick was located at the tuning fork but appeared to be in very bad shape. He was pale and mottled, not his more typical dark gray color. He was working his gill covers in a labored fashion. A 40 cm sunflower sea star *pycnopodia helianthoides* was attached to the tail of the fish. When the fish broke loose from the sea star the swimming motion was unnatural and inefficient, accompanied by shaking spasms. The difficulty in swimming triggered an aggressive response from a smaller (75cm) fish. Perhaps a male looking for an opening? Further observation revealed a silver dollar sized area of different colored and textured skin below the lateral line on the left side below the second dorsal. The caudal fin was missing flesh in the area contacted by the sea star. Continued observation of Nick showed more of the same behavior and led to speculation of his immanent demise.“

These males have defended the same territory from season to season and have used the same cavity for egg masses as shown in Table 5.1. It is interesting to note that one of these fish (Jack) successfully defended prime spawning territory for two seasons but was not able to produce any egg masses. Should estimates of reproductive capacity include a factor for senescence?

Table 5.1 Visually distinct individual male guard fish**.**

Site Fidelity of Individual fish

	Season					
Fish	**97/98**	**98/99**	**99/00**	**00/01**	**01/02**	**02/03**
Split Lip	X	X	<1>			
Jack		X	<2>	<2>		
Max		X	X	X<3>	X	X<5>
Bob		X<4>	X	X	X	X
Nick					X	<1>
Leo					X	X

Notes: X= Nest in same location
<1> Observed on site, believed deceased
<2> Fish on site, no nest
<3> New site 15 ft. south
<4> First site 10 ft. north
<5> New site 10 ft. west

Many of the other nest sites used in repeat years have guard fish with increasing length measurements from year to year raising the possibility of the same guard fish returning to the site. Table 5.2 gives the measured length of the visually distinct guard fish for the seasons.

Table 5.2 Length of Individual Guard Fish (cm)

	Season					
Fish	**97/98**	**98/99**	**99/00**	**00/01**	**01/02**	**02/03**
Split Lip	85	90				
Jack		80				
Max		75	80	80	90	85
Bob		90	90	90	90	90
Nick					90	
Leo					90	85

Notice that two of the measured lengths are greater than a subsequent year, this is considered to be due to inaccurate measurement. The 5 cm difference is within the plus or minus 5 cm tolerance considered to be the practical level of accuracy obtainable by the method used.

Interesting Observations
Guard fish have been observed performing courtship displays for prospective mates. This occurs when a female fish is in the vicinity of the territory of the male fish. Territorial aggression between male fish guarding eggs was also observed. The following passages taken from the survey activity log describe the observed behaviors:

Extracts from Survey Activity Log
(Date, 11/27/02) A large gravid female was observed near two smaller dark gray fish, assumed to be males, at the south end of the east feature of the cathedrals. When the female moved, the male above the female performed a courtship display, fully extending his fins and arching his body while swimming around the female with a quivering motion. This triggered an aggressive response from the second male that was below the female. The two males sparred with each other for a bit and then the second male made some aggressive displays toward the observer. This location has been the site of two nest sites with different guard fish in past seasons.

(Date, 12/14/02) Courtship behavior was observed in the east portion of the enhancements. A large female approached a guarded site drawing a short display from the dark gray male. The female then came and rested at the site and the male did a couple of laps around her with all fins extended and lots of shaking and quivering. A fish guarding a site in the vicinity took great interest in all of this. The female then left and things settled back to same old same old.

(Date, 12/21/02) Max did a courtship display for the ladies. His moves are a little different than others that have been observed. Other males have taken a "U" shaped posture, concave side toward the female. The fish shudders in a fairly uniform frequency of about 3 to 5 cycles per second. The displays last about 5 seconds and the male sort of circles the female remaining in a horizontal plane. Max, on the other hand, takes about a 45 degree nose up posture and makes an "S" shape with his body. His shudders are the same frequency but pausing a beat at about one second intervals. The affect on the females could not be determined.

(Date, 2/08/03) A confrontation between guard fish was seen. It was serious, involving biting, not displays. The fish are guarding adjacent nest sites and both were pretty battered. The observer may have initiated the agon by going between the fish, when one fish went for the observer, the second fish went for the first fish.

Conclusions

Initial efforts concluded that a method and protocol have been established that works with volunteer divers. Although early data looks promising, and it appears that a stable breeding population of lingcod is established in the park; it is too early to draw conclusions. Sufficient data has been gathered to provide a baseline for future monitoring. Effort is being initiated to apply statistical analysis to the data gathered.

For the future, nest sites will continue to be permanently marked with numbered brass tags. This will simplify defining the locations from year to year. Work will continue on more detailed mapping of park features. An effort is underway to improve the database and simplify data entry and recovery.

Further Research and Investigation

Many questions are raised by the information gleaned to date. Do female lingcod return to the same site the way the males do? Do females spawn all at once or in multiple egg masses? Do males select a territory for life, or upgrade? Are the fish in the park more susceptible to predation? Has the park reached saturation density of lingcod? What is the maximum lingcod population, what is the optimum population? The answers to many of these questions require more sophisticated tools such as tagging of fish and DNA analysis. Investigation of these questions is currently beyond the capability of the volunteer dive team and is not permitted in the underwater park.

Acknowledgments

The census would not have been possible without the dedication and hard work of the volunteer dive team, particularly Jim Middleton and Steve Rubin who made many survey dives. Mary Lou Mills, and Wayne Palsson (WFDW) provided advice and encouragement. Dave Rockwell and John Williams provided video records of survey activities. Ken Collins helped to set up database structure and generate data for the census. Thanks are due to all of the above..

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